Function and structure of the farmland shelterbelts in northern area of Shanxi Province

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Abstract: From the 1950s to 1960s, large area of *Populus simonii* shelterbelts system was established in northern area of Shanxi Province. For reconstructing the old shelterbelts, more attentions should be paid to selecting suitable tree species and design of logical shelterbelts structure. In order to provide a profound basis for the efficient establishment of shelterbelts, the study on function and structure of the farmland shelterbelts was conducted in Shuozhou and Datong areas, both are semi-arid areas in Northern Shanxi Province during 1996-2001. The wind-control effects of shelterbelts with different structures (close-spaced, wider-spaced, and widest-spaced) were investigated by portable wind vane and anemometer, wet and dry bulb thermometer, ground thermometer, glass service instrument. The results showed that the wind-control capacity of the shelterbelts during the leafing period should be thought as the criteria index in shelterbelts established. The wider-spaced shelterbelt that was made of 4-6 rows of trees, with a spacing of 2.0 m×3.0 m, had the best wind-control result.

Keywords: Shelterbelts; Wind-control function; Shelterbelts structure
CLC number: S727.2; S792.116 **Document code**: A **Article ID**: 1007-662X(2002)03-0217-04

Introduction

In Northern area of Shanxi Province, for historical and natural reasons, many forest resources were lost and the vegetation coverage has continuously declined (Zhou 1997). Consequently, the environment of this area is being deteriorated and climate has gradually become drier due to frequent occurrence of wind and sandstorms (Wang 1995). In order to improve the living conditions of people, large area of shelterbelt system consisted of *Populus simonii* was established during the 1950s-1960s. After several decades, species composition of the shelterbelts has changed from single species to multiple ones and mixed forest of conifer trees and broadleaf trees has been established (Wang 1992). These shelterbelts could protect farmland against wind and soil erosion (Guo 2000b). However the effects of different shelterbelts structure have not been well studied, and mismanagement is weakening the function of the shelterbelts system (Cui 1990). Based on survey of farmland shelterbelts in northern area of Shanxi Province, this paper analyzed the function, structure and effects of these shelterbelts, so as to provide a profound basis for the efficient management of the shelterbelts.

Research methods

The research sites were located at Shuozhou and Datong, belonging the semi-arid area in Northern of Shanxi Province. All shelterbelts consist of *Populus simonii*, with a raw spacing of 1.0 m ×1.5 m. The structure of shelterbelts could be divided into three types: close-spaced (ventilation coefficient <0.25); wider-spaced ($0.25 \geq$ ventilation coefficient ≥ 0.4); widest-spaced (ventilation coefficient > 0.4) (Guo *et al.* 2000a). The width of shelterbelts ranged from 8.0 m to18.0 m (or 6-11 rows of trees) and tree height ranged from 8.0 m to 10.0 m. Observation was made at different distances from shelterbelts. Wind speed (1m above the ground) was simultaneously measured in different points at fixed time. The soil water content inside or outside shelterbelts was determined at a fixed time by measuring the amount of soil-water loss in evaporation dishes of 20-cm diameter with soil samples. Ground temperature was determined by ground temperature thermometer placed at every point, and the air temperature was measured by wet and dry bulb thermometer. Soil wind-erosion was determined by measuring the amount of soil loss in soil-filled glass dishes after strong wind.

Results and analysis

Wind-control effects

Wind-control effects of the shelterbelts were analyzed by measuring the reduced airflow and its change direction through trees (Lin 1982). When the airflow goes through the shelterbelts, one part of which changes direction and slows down, and the other part causes air turbulences due to the trees existence. These turbulences will buffer and counteract each other, cause a reduction of the wind force and speed (Cao 1981, 1983).

Foundation item: The study was supported by Shanxi Ninth Five-year Plan Project (No. 961016).
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Received date: 2002-04-09
Responsible editor. Zhu Hong

Influence of ventilation coefficient and width of belt

In Jinshatan area, the wind-control effect was measured for the shelterbelts of 8 m, 10 m, 14 m, and 17 m in width. The reduced rate of average wind speed varied with the belt width within a distance of 5H-20H ("H" means tree-height, e.g. "5H" means a distance that is five times tree-height in the lee side of the shelterbelts), (Table 1).

Table 1. Wind-control effects of shelterbelts with different width and ventilation coefficient

Belt	Width /m	Ventilation coefficient	Reduction of wind speed (%)*		D-value
			June 10	May 10	
A	17	0.68	22.9	19.1	3.8
B	8	0.61	31.9	28.9	3.0
C	10	0.63	27.5	24.7	2.8
D	14	0.60	29.3	26.6	2.7

Notes:*---the site was in a distance of 5-20H on the lee side of belts. The angle between wind direction and shelterbelts was 45º-67º.

From Table 1, we can see that there is no regular correlation between wind-control effects and the belt width. Therefore, it can be stated that the reduction rate of the wind speed does not increase with the increasing belt width. The ventilation coefficient, however, had a direct influence on the wind-control effects. If the ventilation coefficient of belt is bigger, the reduction of the wind speed on the lee side of the belt will be less. For example, the shelterbelt (A) with a relative big ventilation coefficient made a 22.9% reduction in the wind speed; while the shelterbelt (D) with relative small ventilation coefficient reduced 29.3% in the wind speed. The shelterbelt (B) had even better result on wind-speed reduction compared to shelterbelt (A). Therefore, it is concluded that within a certain distance, the ventilation coefficient has an obviously negative correlation with the reduction of the wind speed. In the Table 1, the difference in reduction of wind speed between May and June was due to the difference of leaves and twigs, for example, leaf size, leaf and twig number.

Influence of belt structure

In Shuozhou, the wind-control effects of three different structures of *P. simonii* (13-year-old) shelterbelts were investigated during the leafing period (Table 2). Different structural shelterbelts had different wind-control effects. Within a distance of 20H, the wider-spaced belt made of 6 rows, with a ventilation coefficient of 0.4, produced the best result in reduction of wind speed, while the widest-spaced belt which was made of two rows, with a ventilation coefficient of 0.8, had the worst result. The restoration of wind speed, at each observation point of lee side, for both wider-spaced shelterbelts and close-spaced shelterbelts increased slowly from the near distance to the far distance. The reduction rate of the wind speed of the close-spaced belt was higher than that of the wider-spaced belt at 5H and 10H but lower than that at 15H and 20H. This indicated that the general wind-control effect of the close-spaced belt is worse than that of wilder-spaced belt. From Table 2, it can be concluded that the wider-spaced belt is best and the widest-spaced belt is worst in terms of general wind-control result.

Table 2. Wind-control effects of different structural shelterbelts of *P. simonii*

Shelterbelt structure	Rows	Number of trees per meter (trees/m)		Ventilation coefficient	Wind speed In open field (m/s)	Reduction of wind speed in the lee side of shelterbelts (%)					
		Arbores	Bushes			5H	10H	15H	20H	Average	Difference between 5H and 20H
Close-spaced	11	6.0	1.7	0.1	8.0	44.2	40.8	26.6	17.7	32.3	26.5
Wider-spaced	6	3.7	1.0	0.4	6.5	43.0	41.9	35.4	33.8	38 5	9.2
Widest-spaced	2	1.4	0.4	0.8	7.7	27.8	16.8	13.7	8.6	16.7	19.2

Notes: "H" means tree-height; "5H" means the distance of five times tree-height in the lee side of the shelterbelts.

Protective effects on soil-wind erosion

Decreasing the intensity of soil-wind erosion

In the last ten-day of April 2000, wind speed was large in successive six days. At two o'clock in the afternoon on April 20th, the wind speed averaged 11.2 m/s, with a maximum speed of 14.0 m/s. After then, the protective effect on the soil-wind erosion was studied on the lee side of the different structural shelterbelts. The results showed that, in case of strong winds, the shelterbelts could protect the soil from wind erosion. Within a distance of 3H-20H in the lee side of belts, the soil-wind erosion was decreased by 59.7% at the close-spaced belt and decreased by 77.7% at the wider-spaced belts, compared with the open fields (Table 3).

Improving the constitution of topsoil of farmland

In order to study the effects of shelterbelts on soil grain, before land was ploughed in spring, we selected the wider-spaced shelterbelt established in Huzhai Village of Huairen County and the widest-spaced shelterbelts established in Zhaoshibazhuang Village of Shuozhou City as the objects. The results showed that, within a distance of 3H-20 H in the lee sides of the two shelterbelts, the content of soil grain with diameter less than 0.25 mm was 74.7% and 29.1% higher than that in open farmland (Table 4). Since the shelterbelts in Huzhai Village in wider-spaced structure were established earlier than that in Zhaoshibazhuang, at the lee side of the shelterbelts, the

soil grain number of small diameter in the topsoil of farmland was higher than that in Zhaoshibazhuang.

Table 3. Soil-wind erosion under different structural forestbelts

Shelterbelts structure	Erosion depth in open fields /cm	Soil wind erosion depth in farmland /cm 3H	5H	10H	15H	20H	Average	Difference between open Fields and farmland
Wider-spaced	0.77	0.19	0.16	0.15	0.15	0.21	0.17	0.60
(Ventilation coefficient of 0.3)	100%	24.7%	20.8%	19.5%	19.5%	27.3%	22.3%	77.7%
Close-spaced	0.74	0.13	0.33	0.29		0.44	0.30	0.44
(Ventilation coefficient of 0.1)	100%	17.6%	44.6%	39.2%		59.5%	40.3%	59.7%

Table 4. Comparison of the content of soil grain in diameter less than 0.25 mm

Location	Shelterbelts structure	In open farmland (%)	Content of soil grain at the lee side of the shelterbelts (%) 3H	5H	10H	15H	20H	30H	Average	Difference of soil grain between the lee side of the shelterbelts and open farmland (%)
Zhaoshibazhuang	Widest-spaced shelterbelts	100	129.3	136.4	137.0	136.4	120.2	115.4	129.1	29.1
Huzhai	Wider-spaced shelterbelts	100	221.1	211.1	148.0	154.7	137.8		174.7	74.7

Influence of shelterbelts on the climate

On air temperature and soil temperature

According to observations in May 2000, the daily average air temperature in a 20-year-old *P. simonii* plantation and farmland in Jinshatan was 0.3 °C, lower than that in an open field. The maximum air temperature was 1.0-2.0 °C; and the minimum air temperature was 0.8-1.4 °C. This shows that the daily variation of air temperature in the plantation and farmland was lower than that outside. This is due to the fact that the shelterbelts reduced the vertical and horizontal air current; weaken the exchange of heat and cool air up and down (Wang 1993).

The influence of shelterbelts on the soil temperature showed positive results (Yan 1993). Our observations showed that the average soil temperature under layers of 5 cm, 10 cm, 15 cm, 21 cm at 5H distance from the lee side in shelterbelt was 1.1 °C, 0.3 °C, 0.3 °C, and was 0.2 °C higher than that at 25H distance from the lee side in shelterbelts respectively in the last ten-day of May.

On air and soil humidity

Since shelterbelts can reduce the wind speed and vertical turbulences, the exchange of dry air and wet air up and down near belts also decreases (Guo *et al.* 2000a). Our research showed that the relative air humidity in forests was increased by 2.8-4.0%, and the absolute humidity was increased by 0.7-1.1 mb. The influence of shelterbelts on air humidity however varies with weather conditions.

Evaporation of soils is determined by the saturation deficit of air temperature, wind and air humidity. By reducing wind speed, decreasing air temperature, and increasing relative humidity (decrease the saturation deficit), the shelterbelts could lead to a decrease in soil water evaporation (Yu 2000). Our research showed that, during May and June in Jinshatan, the average water content in the soil at a distance of 5H-20H from the lee side in the 20-year-old *P. simonii* shelterbelts (10 m width, 0.63 ventilation coefficient) was increased by 8.2%-13.6% compared to that in an open field, within 48 hours.

Assessment of protection effectiveness

The research results showed that at a distance of 5H from lee side of shelterbelts the wind speed could be reduced averagely 37.9%, and at 5H-20H averaged 28.1%. The air temperature in the shelterbelts was increased by 0.5-10 °C on average and the soil temperature (soil layers under 5 cm) could be increased by 1.0 °C. At a distance of 25H from lee side of the shelterbelt, the air relative humidity was raised on average by 4.0% and the absolute humidity by 1.1 mb, and the evaporation of the soil water was also obviously lower than that of open field. The changes of these climate factors are very important for semi-arid area (Ci 1980), because they create better conditions for growing crops. Under protection of shelterbelts, the soil-wind erosion of the farmland decreases and soil fertility is improved because the wind force is reduced. For example, in 2000, the harvest of maize grown within diversified shelterbelts structures was 15.0%-28.3% higher than that in open field.

In northern Shanxi Province, strong wind usually occurs in March and May, the leafing period of trees. Therefore, the wind-control capacity of the trees during the leafing period should be the criteria for establishing shelterbelts. The structure of the shelterbelts determines the wind-control capacity. Our research results showed that the wider-spaced shelterbelt, with plant spacing of 2 m ×3 m, composed of 4-6 rows of trees, had best wind-control result.

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